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Mapping the distribution of deep-sea corals in the Northern Gulf of St. Lawrence using both scientific and local ecological knowledge

Cartographie de la répartition des coraux de grande profondeur dans le nord du Golfe du Saint-Laurent basée sur les connaissances scientifiques et écologiques de la région

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ABSTRACT

While over 50 species of deep-sea coral have been identified in Atlantic Canada, little is known about the corals found in the waters off the west coast of Newfoundland and in the Northern Gulf of St. Lawrence in general. This study uses three sources of information to identify coral species found in the Northern Gulf and to map their distribution. DFO groundfish survey records from the Gulf were combined with fisheries observer records of coral bycatch. Interviews were then conducted with 28 west coast Newfoundland fishermen to determine which species of deep-sea coral they have seen come up in their gear. All 3 data sources confirm that nephtheid soft corals are common in the Northern Gulf. DFO trawl surveys and fishermen interviews both found sea pens to be common in the deep channels present in the Northern Gulf (Anticosti and Esquiman Channels). Large gorgonians are missing from the DFO trawl survey and observer records, but, *Primnoa resedaeformis, Keratoisis ornata* and *Acanthogorgia armata* were reported as being present in the Northern Gulf from fishermen interviews. Fishermen observed large gorgonians in longline gear which was likely deployed on rocky bottoms which may not be able to be sampled by the DFO trawl survey program. Fishermen described an association between high bycatch of sea pens and high catch rates of shrimp, cod and Atlantic halibut.

RESUMÉ

Bien qu'on ait répertorié plus de 50 espèces de coraux de grande profondeur dans la partie canadienne de l'océan Atlantique, on en sait bien peu sur les coraux au large de la côte Ouest de Terre-Neuve et dans la partie nord du Golfe du Saint-Laurent. La présente étude s'appuie sur trois sources d'information pour répertorier les espèces de coraux que l'on retrouve dans la partie nord du golfe et en cartographier la répartition. À cette fin, on a combiné les relevés sur les poissons de fond du golfe et les rapports d'observation sur les prises accessoires de coraux. On a mené des enquêtes auprès de 28 pêcheurs de la côte Ouest de Terre-Neuve pour savoir quelles espèces de coraux ils avaient repêchées dans leurs engins. Les trois sources d'information confirment que les coraux mous nephteides se trouvent couramment dans la partie nord du golfe. Les relevés de pêche au chalut du MPO et les enquêtes auprès des pêcheurs révèlent tous deux que les plumes de mer sont abondantes dans les chenaux profonds de la partie nord du Golfe (Chenaux Anticosti et Esquiman). Les grandes gorgones sont absentes des relevés de pêche au chalut du MPO et des rapports d'observation, toutefois, les espèces *Primnoa resedaeformis, Keratoisis ornata* et *Acanthogorgia armata* ont été signalées par les pêcheurs du nord du golfe interrogés. Par ailleurs, des pêcheurs ont observé sur les palangres de grandes gorgones, sans doute déployées sur des fonds rocheux, qui ne pourront pas être échantillonnées au moyen de la pêche au chalut. Des pêcheurs ont établi une corrélation entre les taux élevés de prises de plumes de mer et ceux des crevettes, morue et flétan.

INTRODUCTION

The deep-sea corals of Atlantic Canada have recently received increased attention due to concerns raised about the impact of commercial fishing activities on benthic ecosystems (Watling & Norse 1998, Edinger et al. 2007a, Fuller et al. 2008). While coral distribution data now exist for the continental margin of Atlantic Canada (i.e. Gass & Willison 2005, Wareham & Edinger 2007, Cogswell et al. 2009), there has been little done to map the distribution of deep-sea corals in the Northern Gulf of St. Lawrence, encompassing NAFO (Northwest Atlantic Fisheries Organization) divisions 4R, 4S and 3Pn. This study aims to fill information gaps on the distribution of deep-sea corals in the Northern Gulf. Results from coral bycatch records from DFO groundfish survey trawls and fisheries observer records were combined with results from interviews with Northern Gulf fishermen to learn more about which species of coral are present in the Northern Gulf, their distribution, and possible fisheries impacts on them. This method is similar to that of Gass and Willison (2005) in that we used three sources of information to determine the distribution of deep-sea corals.

Many communities on the Northern Gulf of St. Lawrence remain active in the fishery and fishermen provide a wealth of knowledge coming from repeated, long-term interactions with the marine environment. Therefore, their knowledge of deep-sea corals is a valuable resource, especially considering the high costs of deep sea research. For example, coral hot spots explored in Edinger et al. (2007a) were first identified from fishermen interviews done by Gass and Willison (2005).

The Northern Gulf of St. Lawrence lies on the continental shelf; therefore, we would expect less coral diversity than on the continental slope which has a greater range of habitats (Wareham & Edinger 2007). While the majority of the Northern Gulf is less than 200m deep, there are deep-water channels such as the Esquiman and Anticosti Channels (see Figure1) that contain slope water which remains above 0°C year-round. These channels have steep slopes, suitable bottom temperatures, and currents which all make suitable habitat for deep-sea corals (Bryan & Metaxas 2007). In addition, some species of deep-sea coral previously identified in the Northwest Atlantic are able to live in soft, muddy substrates like those found at the bottom of these channels. These include sea pens (Pennatulacea).

Several recent studies have discussed the potential ecological importance of deep-sea corals for fish (Husebø et al. 2002, Krieger & Wing 2002, Auster 2005, Auster 2007, Edinger et al. 2007b). Many fishermen in the Northern Gulf have had experience fishing for a variety of species using a variety of gear types. Therefore, they may be able to provide information on any apparent relationships between deep-sea coral and fish from their experience. The Northern Gulf has a long history of commercial fishing. Parts of it were heavily bottom-trawled for groundfish prior to the cod moratorium in 1994 and other areas had intensive coastal cod trap and deeper water longline and gillnet groundfish fisheries until that time. Since the moratorium, bottom-trawling for cod has ceased, but longlining and gillnetting for cod has continued at a much smaller spatial and temporal scale along with similar fisheries for other groundfish species such as Atlantic halibut (*Hippoglossus hippoglossus*) and turbot (*Reinhardtius hippoglossoides*) . Some areas also continue to be heavily trawled for shrimp (*Pandalus borealis*) since the cod moratorium in NAFO division 4R. Existing research suggests that all of these gears (shrimp trawl, longline and gillnet) can intercept and potentially damage deep-sea corals (Edinger et al. 2007a, Fuller et al. 2008).

METHODS

DFO GROUNDFISH SURVEY TRAWL RECORDS

Records for all DFO groundfish survey trawls from 2001-2009 were obtained from DFO Quebec Region in Mont-Joli. These records include data on the presence and location of corals in the Northern Gulf as well as information on areas where no deep-sea corals were observed. Information included in the trawl survey data includes location, depth, bottom temperature, salinity, identity, number of samples and biomass. Corals were identified to the best of the ability of the DFO groundfish technicians onboard using coral identification guides based upon the ID guides developed in the Maritimes and Newfoundland regions. Data from the trawl surveys were imported and mapped using ArcMap version 9.3.

FISHERIES OBSERVER RECORDS

Fisheries observer bycatch records for corals in the Northern Gulf were obtained from DFO Quebec Region for the years 2001-2008. While these records are not as comprehensive as those for DFO groundfish survey trawls, information on location, depth found, targeted species and gear types are included. Consistent with previous research, fisheries observer records are treated as presence data only, rather than presence-absence, as observers often do not have the ability to search each set for corals. Data from fisheries observer records were imported and mapped using ArcMap version 9.3.

INTERVIEWS WITH NORTHERN GULF FISHERMEN

Interviews were conducted with 28 Northern Gulf fishermen in November and December 2009 in three communities on the west coast of Newfoundland. These communities were Port-Au-Choix, on the Northern Peninsula of Newfoundland, Norris Point, located in the Bonne Bay Area, and Port-Aux-Basques, located at the southwest corner of Newfoundland (Figure 1). The number of fishermen interviewed in each community is indicated in Table 1. Port-Au-Choix was chosen because this is where the Newfoundland fleet of shrimp trawlers in the Northern Gulf is based. Norris Point was chosen because it is the location of the Bonne Bay Marine Station of Memorial University. Fishermen in the Bonne Bay area target a variety of groundfish species including cod and turbot using both longlines and gillnets. Port-Aux-Basques was chosen because it is the location of the longline fleet in NAFO division 3Pn. They target both cod and Atlantic halibut using longlines.

Table 1: Number of fishermen interviewed fishing out of each community.

Community	No. Interviews
Port-Au-Choix	11
Norris Point	7
Port-Aux Basques	10

SAMPLE RECRUITMENT

Contact was made with local elected representatives of the FFAW (Fish Food and Allied Workers) who provided names of potential interviewees in each community. At the end of each interview, we would ask the interviewee for names of other local fishermen deemed to be experienced and knowledgeable about the marine environment and Northern Gulf fisheries. This process of obtaining new names is known as snowball sampling (Goodman 1961) and is commonly used in local ecological knowledge (LEK) research (see Neis & Felt 2000).

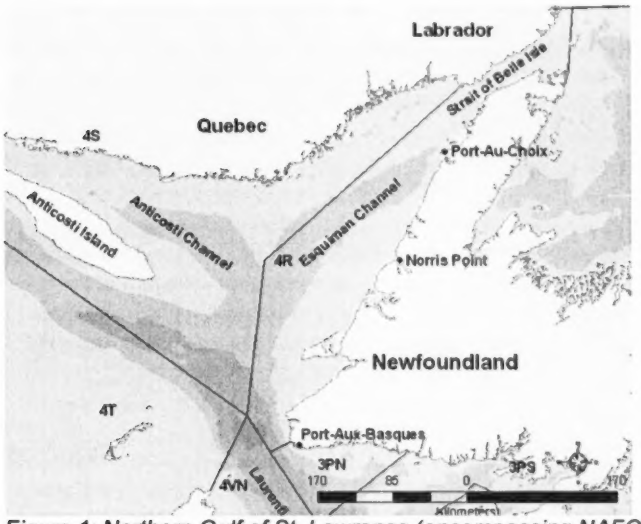

Figure 1: Northern Gulf of St. Lawrence (encompassing NAFO divisions 4R, 4S and 3PN).

INTERVIEWS

Semi-structured interviews were used, in which, a fixed list of questions is asked in every interview with room for expansion on certain topics. Questions on the fisherman's career, experience, target species, gear-types, deep-sea coral identification and distribution, impacts of different gears and opinions about conservation were all addressed. In many cases the interviewed fishermen could identify species or groups of coral that they had previously seen but were unable to place where these corals were encountered on a map. When a fishermen could remember the location where they encountered coral, this is referred to in this paper as a map-able observation. The interviews were not recorded. A research assistant typed up the interview transcripts while the interviews took place. The DFO identification guide for deep-sea corals in the Newfoundland & Labrador region was used during the interviews along with preserved coral specimens borrowed from DFO Newfoundland region.

CHART DRAFTING

Locations of fishing areas and coral distribution data were mapped directly in Arc Map (version 9.3) during interviews using a Lenovo tablet laptop. Interviewees were asked to draw polygons on nautical charts (from the Canadian Hydrographic Service) representing their fishing areas and areas they remember seeing coral. These polygons were assigned numbers and were described in further detail in the interview transcripts.

RESULTS

A total of 11 species of deep-sea corals were recorded in the Northern Gulf of St. Lawrence. The greatest number of records came from the DFO groundfish survey trawl program, but the greatest diversity of species was recorded in the interviews with fishermen (Table 2). The distribution of Neptheid (soft corals), *Anthomastus grandiflorus*, and sea pens *(Pennatulacea spp.)* are shown in Figures 2 to 4.

Table 2: Number of coral observations from three data sources (DFO groundfish survey trawls, fisheries observer records and fishermen interviews).

Group	Species	No.sets with coral species observed (DFO)	No. FOP sets with coral species observed	Fishermen interviews	Map-able observations from fishermen interviews
Soft corals	Neptheid spp. (*Gersemia rubiformis*, *Duva florida*, Soft coral unknown)	380/7565 (5%)	3	24/28 (85.7%)	19/28 (67.9%)
	Anthomastus grandiflorus	4/7565 (0.05%)	N/A	11/28 (39.3%)	3/28 (10.7%)
Sea pens	Pennatulacea spp.	459/7565 (6.1%)	N/A	16/28 (57.1%)	10/28 (35.7%)
Cup corals	Scleractinia spp.	N/A	N/A	6/28 (21.4%)	1/28 (3.6%)
Small gorgonians	*Acanella arbuscula*	N/A	N/A	3/28 (10.7%)	0/28
	Radicipes gracilis	N/A	N/A	4/28 (14.3%)	0/28
Large Gorgonian	Acanthogorgia armata	N/A	N/A	11/28 (39.3%)	3/28 (10.7%)
	Antipatharia spp.	N/A	N/A	1/28 (3.6%)	0/28
	Keratoisis ornata	N/A	N/A	3/28 (10.7%)	3/28 (10.7%)
	Paragorgia arborea	N/A	N/A	1/28 (3.6%)	0/28
	Primnoa resedaeformis	N/A	N/A	6/28 (21.4%)	2/28 (7.1%)

DFO GROUNDFISH SURVEY RECORDS

A total of 7,565 trawl survey records were obtained from DFO Quebec Region. These were records for both the presence and absence of coral for all sets from 2001-2009. While not all these records fall directly in the NAFO divisions 4R, 4S and 3Pn, they were included when they were located close to the Northern Gulf. The majority of sets had no coral (Figure 5) with only 11.1% of sets containing coral (88.9% of sets with no coral). 6.1% of sets contained sea pens, 5% of sets contained Nephtheid soft corals and 0.05% contained *Anthomastus grandiflorus*. Coral biomass for both Nephtheid soft corals and sea pens was highest in the Laurentian Channel (Figure 6).

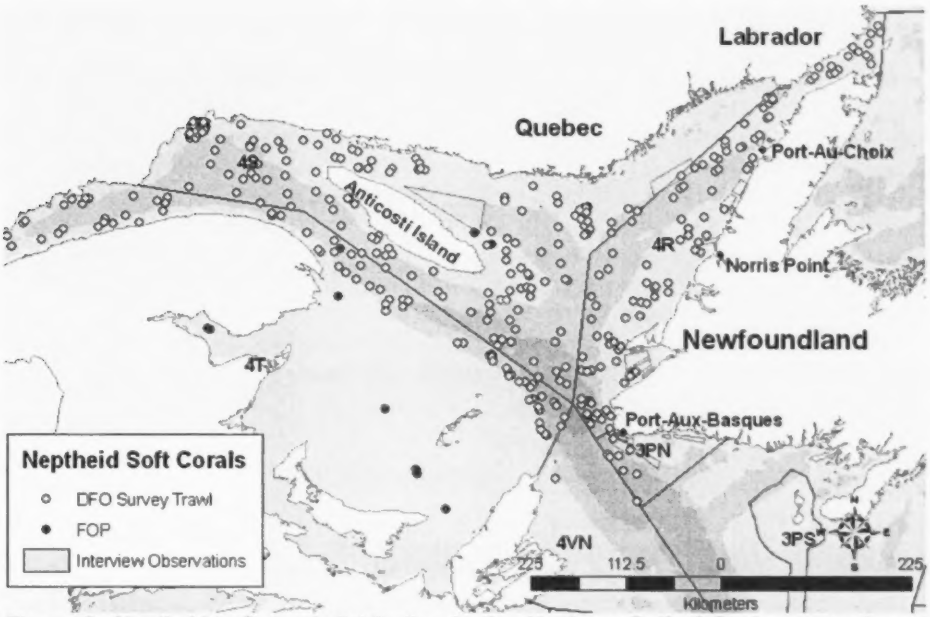

Figure 2: Neptheid soft coral distribution in the Northern Gulf of St. Lawrence based on three data sources (DFO groundfish survey trawls, fisheries observer records and fishermen interviews).

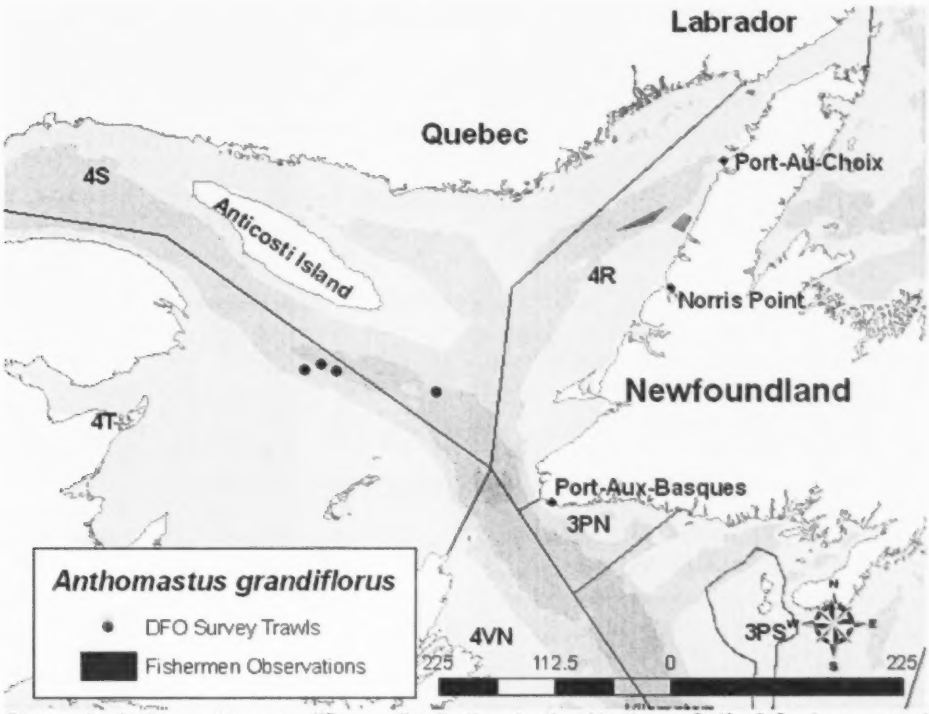

Figure 3: Anthomastus grandiflorus distribution in the Northern Gulf of St. Lawrence based on DFO groundfish survey trawl records and fishermen interviews.

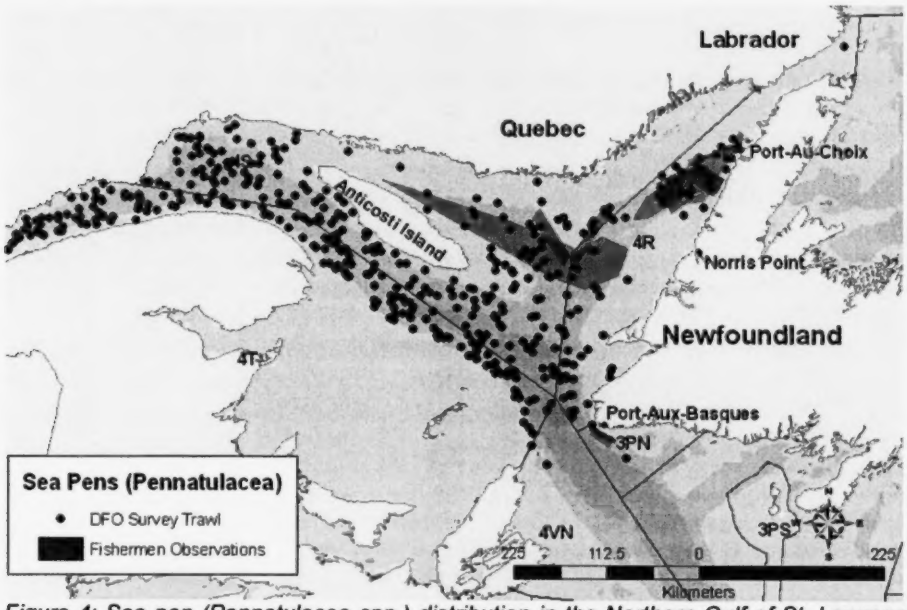

Figure 4: Sea pen (Pennatulacea spp.) distribution in the Northern Gulf of St. Lawrence based on DFO groundfish survey trawl records and fishermen interviews.

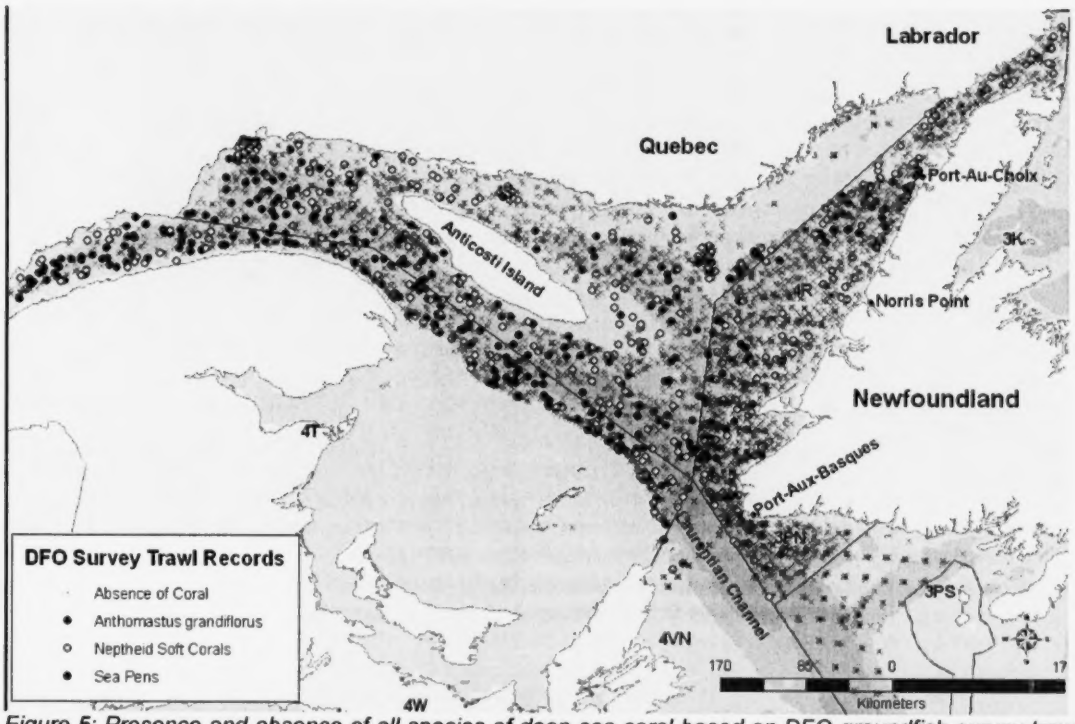

Figure 5: Presence and absence of all species of deep-sea coral based on DFO groundfish survey trawl records.

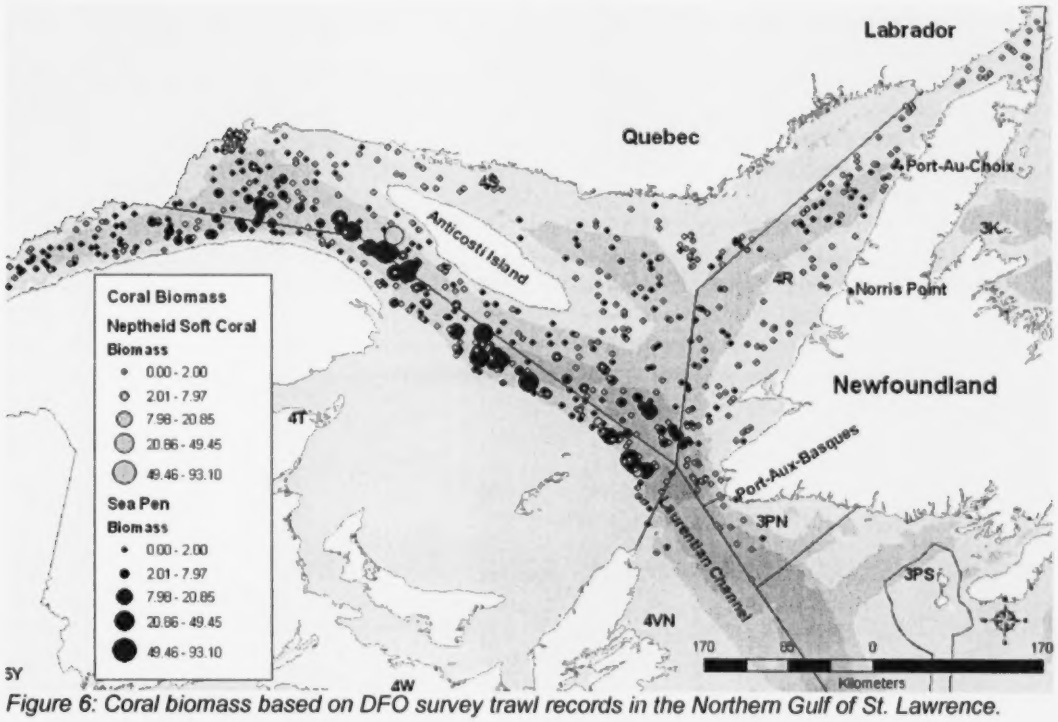

Figure 6: Coral biomass based on DFO survey trawl records in the Northern Gulf of St. Lawrence.

FISHERIES OBSERVER RECORDS

Eleven records exist for corals in the Northern Gulf of St. Lawrence and nearby areas from fisheries observer data. All of these are for the Nephtheid soft coral (*Duva florida)*. Of these 11 records, only 3 of them fall within the geographic boundaries of this study and are found in NAFO division 4S (Figure 7).

INTERVIEWS WITH NORTHERN GULF FISHERMEN

Roughly half of the area of the Northern Gulf was covered by observations from fishermen interviews (Figure 8). As shown in Figure 9, fishermen were more readily able to identify species or groups of deep-sea corals that they had seen, than they were able to place specific locations of encounters on maps. Some groups, such as the small gorgonians (*Acanella arbuscula* and *Radicipes gracilis*), were identified as being observed in the Northern Gulf, but interviewees were unable to place where they encountered those coral species on a map (see Figure 9). This was also the case with Antipatharians (black corals). Many of the map-able observations came from fishing the same grounds consistently and encountering coral on a regular basis.

Nephtheid soft corals and sea pens were the most common groups of deep-sea corals identified from the interviews (see Table 2). 85.7% of fishermen interviewed were familiar with nephtheid soft corals and 67.9% of interviewees were able to place where they encountered nephtheids on a map. 57.1% of fishermen interviewed had seen sea pens in the Northern Gulf and 35.7% were able to place these encounters on a map.

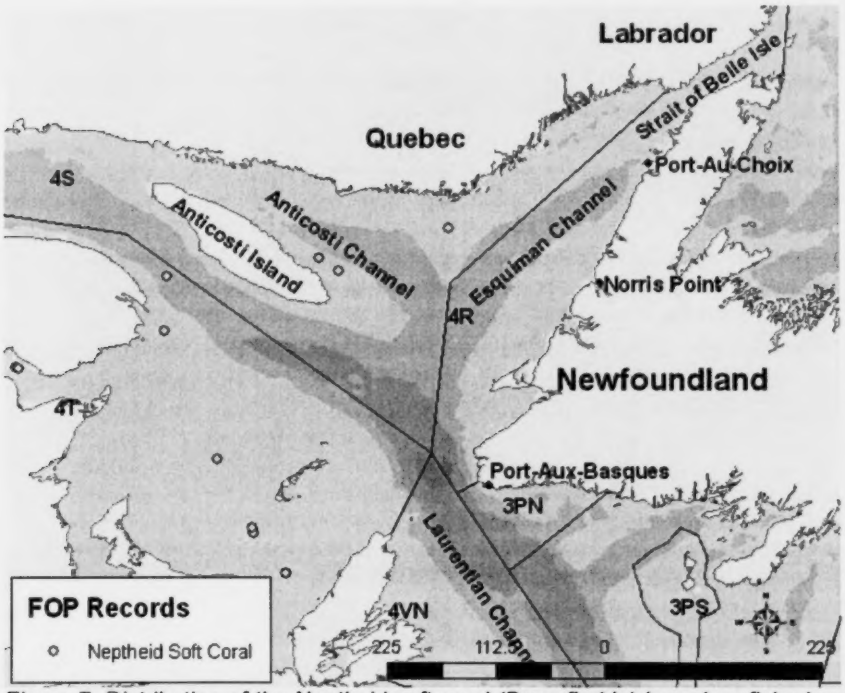

Figure 7: Distribution of the Neptheid soft coral (Duva florida) based on fisheries observer records in the Gulf of St. Lawrence.

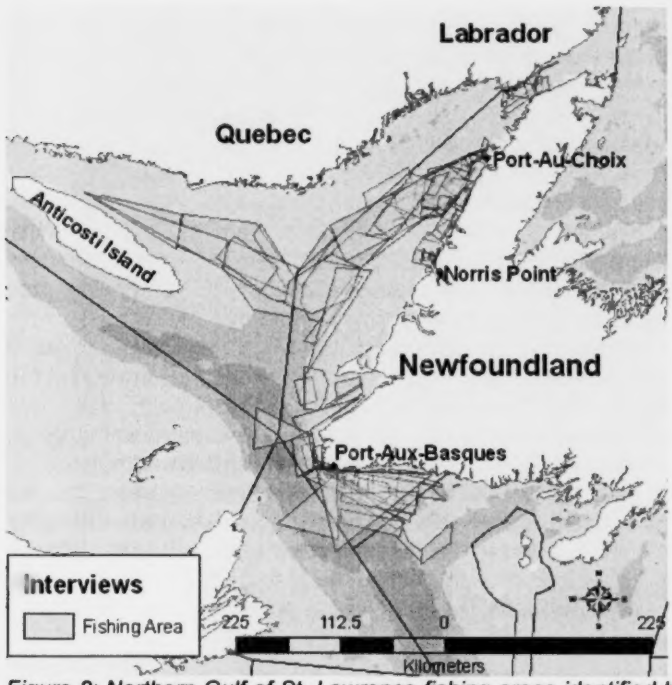

Figure 8: Northern Gulf of St. Lawrence fishing areas identified by interviewed fishermen (multiple target species and gear types).

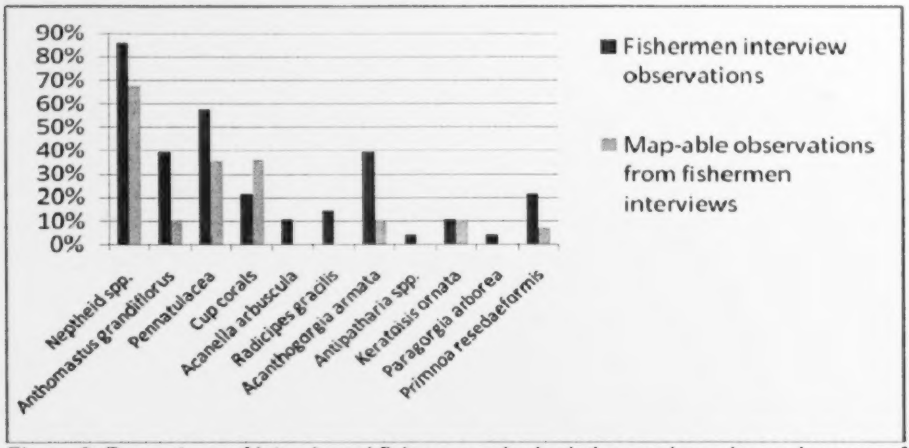

Figure 9: Percentage of interviewed fishermen who had observed species and groups of deep-sea corals in the Northern Gulf of St. Lawrence.

In addition to Nephtheid soft corals and sea pens, the soft coral *Anthomastus grandiflorus* was identified and mapped (Figure 3), along with cup corals (Figure 10) and the large gorgonians *Acanthogorgia armata* (Figure 11), *Keratoisis ornata* (Figure 12) and *Primnoa resedaeformis* (Figure 13).

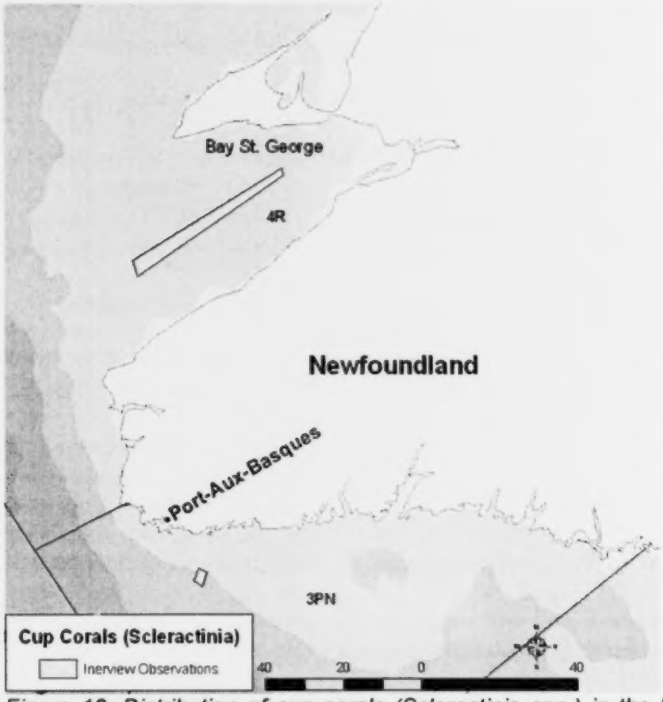

Figure 10: Distribution of cup corals (Scleractinia spp.) in the Northern Gulf of St. Lawrence based on fishermen interviews.

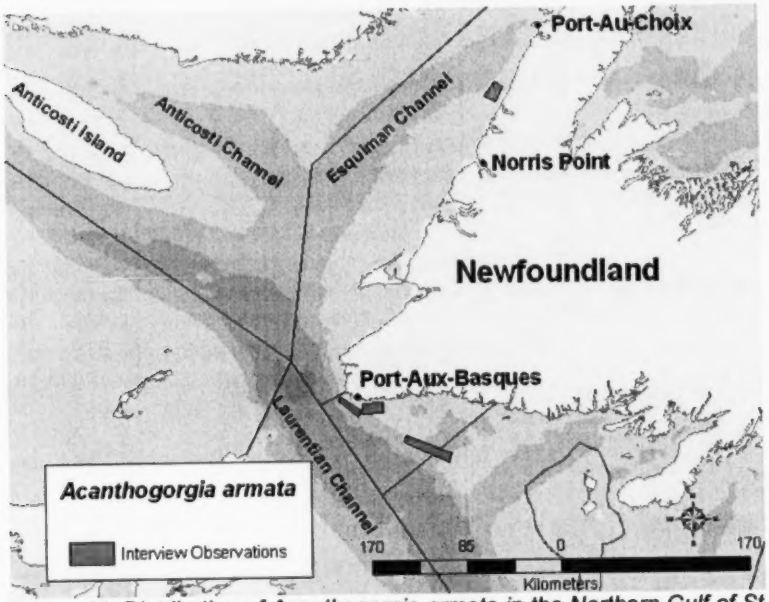

Figure 11: Distribution of Acanthogorgia armata in the Northern Gulf of St. Lawrence based on fishermen interviews.

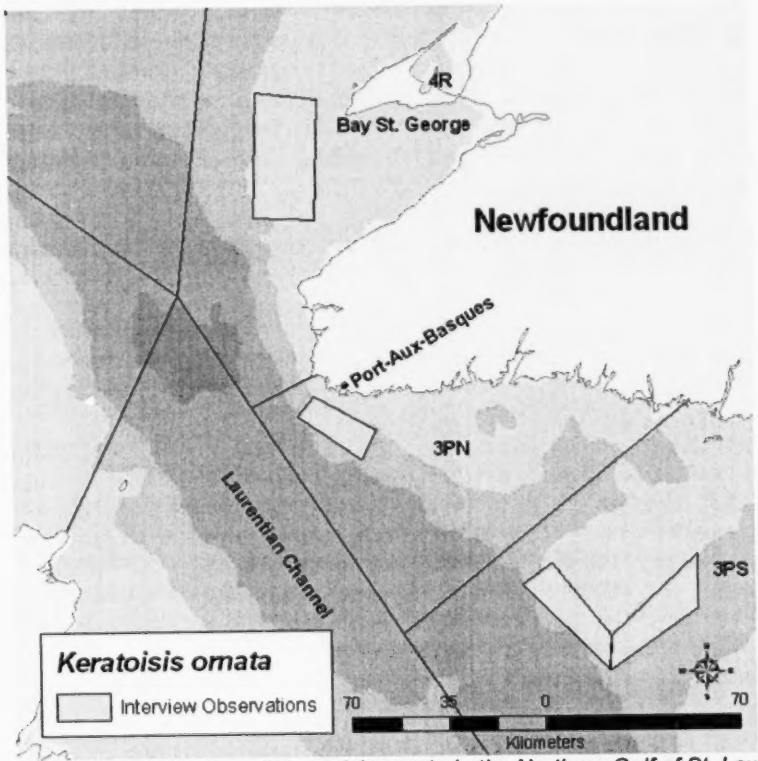

Figure 12: Distribution of Keratoisis ornata in the Northern Gulf of St. Lawrence based on fishermen interviews.

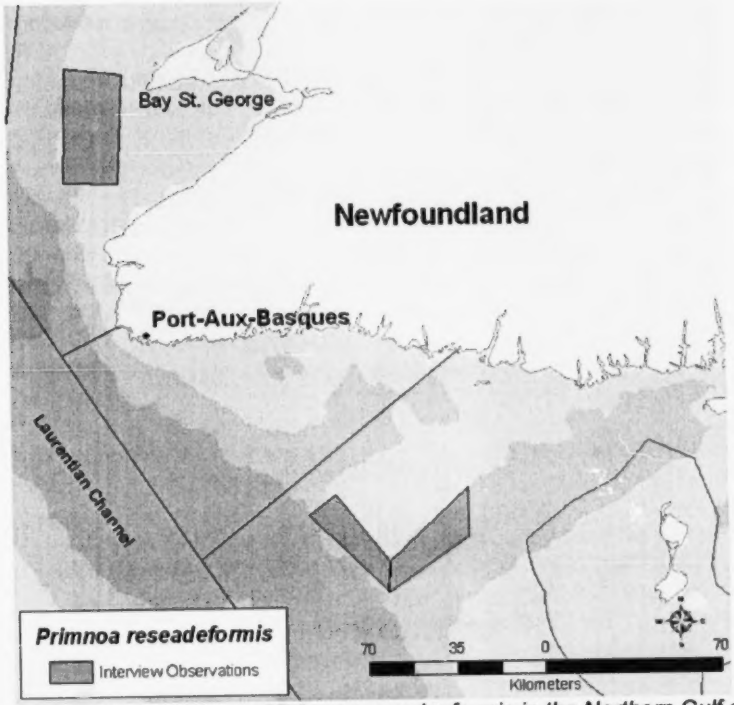

Figure 13: Distribution of Primnoa resedaeformis in the Northern Gulf of St. Lawrence based on fishermen interviews.

DISCUSSION

SUMMARY OF DISTRIBUTION PATTERNS

Nephtheid soft corals, including *Gersemia rubiformis* and *Duva florida*, appear to be the most common group of deep-sea corals found in the Northern Gulf. They appear to be found in all regions where hard substrate is available in depths varying from less than 10m down to more than 500m. They are also found in some of the larger bays found on the west coast of Newfoundland including Bay St. George and Bonne Bay. Bonne Bay has a significant freshwater component and soft corals have been described from the East Arm of the bay suggesting that Neptheid soft corals may be able to endure estuarine conditions or are located below the freshwater layer.

Sea pens, order Pennatulacea, also appear to be fairly common in the Northern Gulf. They were found in the soft bottom of the deeper channels of the Gulf including the Esquiman and Anticosti Channels. From DFO trawl survey records both sea pens and Nephtheid soft corals had the highest biomass in the Laurentian Channel, the deepest channel in the Gulf.

The soft coral (*Anthomastus grandiflorus*) was described by both DFO survey trawls and fishermen interviews, although in different regions of the Gulf. This suggests that while *Anthomastus grandiflorus* is found in the Gulf, it is not as common as the Nephtheid soft corals and sea pens. Similarly, Nephtheid soft corals and sea pens are the most common corals along the continental margins of Newfoundland and Labrador (Wareham & Edinger 2007).
While small gorgonian corals (*Acanella arbuscula* and *Radicipes gracilis*) were identified from the fishermen interviews, no map-able observations were made. Large gorgonians were

identified and mapped from fishermen interviews; these included: *Acanthogorgia armata*, *Primnoa resedaeformis* and *Keratoisis ornata*. Both *Primnoa resedaeformis* and *Keratoisis ornata* were identified as being present off Port-Aux-Basques and in the mouth of Bay St. George. *Keratoisis ornata* has been identified as being present off Port-Aux-Basques from previous reports (Gass and Willison 2005, Cogswell et al. 2009), but these are the first records of *Acanthogorgia armata* and *Primnoa resedaeformis* to date.

Temperature data shows that these areas off Port-Aux-Basques and Bay St. George (Figure 14) have warmer bottom temperatures at shallower depths than other areas in the Northern Gulf. These areas are located on the shelf break where strong currents, suitable temperatures and hard substrates are available for gorgonian corals at these depths.

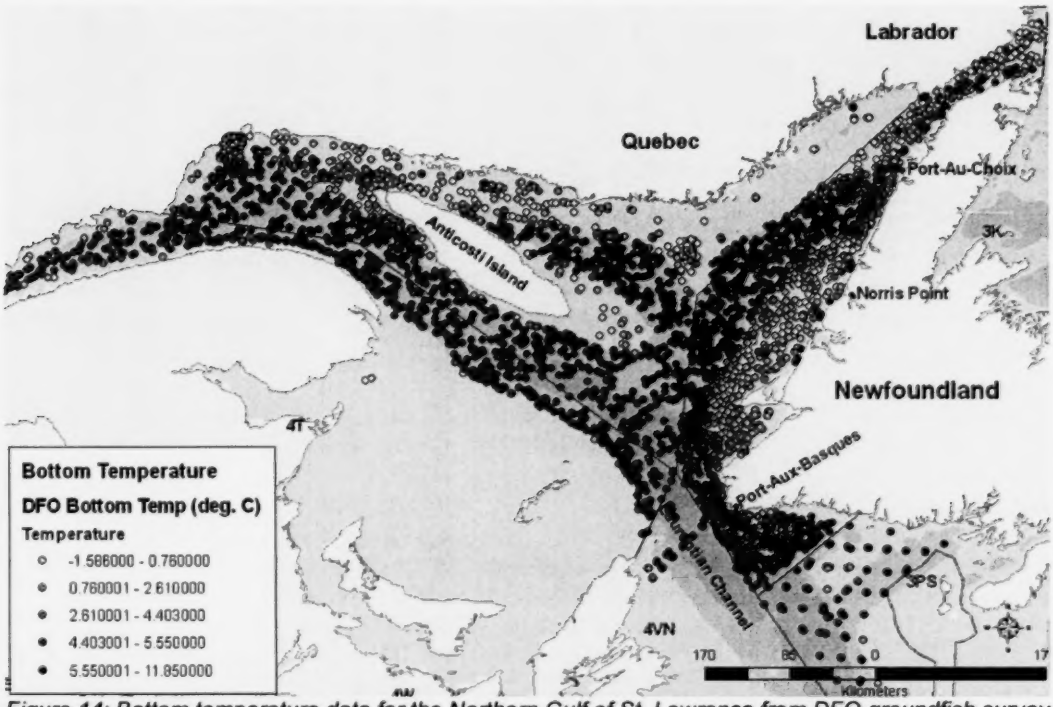

Figure 14: Bottom temperature data for the Northern Gulf of St. Lawrence from DFO groundfish survey trawl records.

A number of species of deep-sea coral, in particular large gorgonians, were identified from fishermen interviews but were absent from DFO survey trawl data and fisheries observer records. This demonstrates the utility of fishermen's knowledge in getting detailed information about the marine environment. The large gorgonians (including *Acanthogorgia armata*, *Primnoa resedaeformis* and *Keratoisis ornata*) have not been caught in DFO survey trawls in the 3Pn area or anywhere else in the Gulf. While these areas have been sampled by DFO trawl surveys (see Figure 14) it is possible that these corals are found on the hard substrate of steep ledges where it is not possible for DFO to use the mobile bottom-trawl used in their scientific surveys. DFO trawl surveys in steep terrain often target the tops of ridges, in order to complete depth-constant trawls of standardized length, hence missing the steepest and rockiest terrain in an area (Wareham & Edinger 2007). In contrast, the groundfish fishery in NAFO division 3Pn is entirely hook and line (long-line) and it is possible to fish areas with rougher seafloor.

As evident in Figures 2,3 and 4, the interview data on the distribution of soft corals and sea pens mirrors what has been recorded from DFO survey trawls and fisheries observer data. A benefit of using multiple sources of data is the overlapping of different data sources to help confirm validity of results. In addition, when using multiple data sources, it is possible that one data source will provide information on unique areas as well. When conducting interviews with fishermen in Nova Scotia and Eastern Newfoundland, Gass and Willison (2005) found that using three sources of data yielded more information than focusing on just one.

ECOLOGICAL INTERACTIONS BETWEEN SEA PENS AND FISH

Of the interviewed fishermen, 43% (12/28) identified areas where sea pens were found to be good fishing grounds for a variety of commercial species using different gear types. Off Port-Au-Choix, in the Esquiman Channel, interviewed fishermen reported that areas with sea pens contained more northern shrimp (*Pandalus borealis*). They employ a shrimp trawl with a nordmøre grate to reduce bycatch of groundfish species. Even with the grid, it is common to catch sea pens and many of the fishermen believed their catch was better when they saw sea pens in their gear.

Fishermen from Port-Aux-Basques also identified sea pen areas as being good grounds for Atlantic cod (*Gadus morhua*) and for Atlantic halibut (*Hippoglossus hipposglossus*). This is not surprising as halibut are usually found in deeper waters at depths known to contain sea pens. Longline is employed in these fisheries and it was reported that sea pens are able to get hooked directly and brought up in the gear. Fishermen reported areas with sea pens to have more and larger halibut than non-sea pen areas. In fact, one fishermen specifically targeted sea pen meadows because of previous good catches in these areas.

One of the next steps with our research is to compare coral abundance and distribution data from DFO groundfish survey trawls and interviews with catch data for a variety of fish species, both commercial and non-commercial. A comparison of trawl catch rates with coral bycatch rates found that sea pens may provide important habitat for both fish (e.g. witch flounder, *Glyptocephalus cygnoglossus*) and benthic invertebrates (e.g. northern shrimp, *Pandalus borealis*) on the Atlantic continental margin of Newfoundland and Labrador (Edinger et al. 2007b).

CONCLUSIONS AND RECOMMENDATIONS

The Northern Gulf of St. Lawrence appears to have a lower coral diversity than surrounding areas in Atlantic Canada (Gass & Willison 2005, Wareham and Edinger 2007, Cogswell et al. 2009, Wareham 2009). This is not surprising as the Northern Gulf lies on the continental shelf while the greatest diversity of deep-sea corals in Atlantic Canada has been reported from continental slope and deeper submarine canyons.

While the hot spot approach has been used to protect coral in other areas in Atlantic Canada, i.e. Nova Scotia coral closures, the best way to protect deep-sea corals and associated benthic habitat in the Northern Gulf may be to adopt a representative areas approach.

One area in the Northern Gulf stands out for higher coral diversity. The area at the mouth of Bay St. George had large gorgonian corals reported from fishermen interviews in Gass & Willison (2005), see also Cogswell et al. (2009), and in the current study. At the moment, there is no bottom trawling or gillnetting in this area, however, longlines are still able to catch and

impact deep-sea corals (Edinger et al. 2007a). Underwater *in situ* observation of this area, either from CAMPOD or ROV in the near future is suggested.

There were few records of coral bycatch collected by the fisheries observer program in the Northern Gulf suggesting that there are no strict requirements regarding the recording of coral bycatch in that program. For example, the northern shrimp fishery has 100% observer coverage (DFO 2009) in areas known to have sea pens from both DFO groundfish survey trawls and interviews, however, no sea pen records exist in the fisheries observer data. We suggest that Northern Gulf fisheries observers receive training in basic coral identification and that they be required to record coral bycatch. Fisheries observer data has proven to be very useful in determining coral distribution in the Newfoundland and Labrador Region (Wareham & Edinger 2007, Wareham 2009). Along with an improved coral recording program, we would advise improved cooperation and communication between the fisheries observer program in the Northern Gulf and both DFO and university researchers.

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